U.S. Army RDECOM-ARDEC
RDAR-MEE-M
Picatinny Arsenal, NJ

Armament Related Corrosion Studies & Sensor Prototyping

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

U.S. Army Corrosion Summit 2010

Presented by: Daniel P. Schmidt
February 11, 2010

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
11 FEB 2010		**00-00-2010 to 00-00-2010**

4. TITLE AND SUBTITLE	5a. CONTRACT NUMBER
Armament Related Corrosion Studies & Sensor Prototyping	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **U.S. Army RDECOM-ARDEC,RDAR-MEE-M,Picatinny Arsenal,NJ,07806**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES
2010 U.S. Army Corrosion Summit, Huntsville, AL, 9-11 Feb

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**21**	

Outline

- Overview
  - ARDEC & our mission
  - Accelerated Corrosion Facility at Picatinny
- On-going Corrosion Studies
- Materials Printing / Corr Sensor

AMC

RDECOM

ARDEC

Armament Research, Development & Engineering Center (ARDEC)

Vision:

Innovative Armaments Solutions for Today and Tomorrow

Mission:

To develop and maintain a world-class workforce to execute and manage integrated life-cycle engineering processes required for the research, development, production, field support and demilitarization of munitions, weapons, fire control and associated items

Locations:

- **Picatinny Arsenal, NJ**
- Benet Labs (Watervliet Arsenal), NY
- Rock Island Arsenal, IL
- Adelphi & APG, MD

Providing the lethality technology for over 90% of the Army's munitions

Overview:
ARDEC Mission

Electro Magnetic Gun

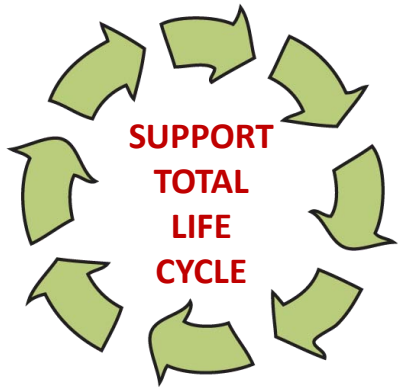
Small/Cannon Caliber Ammunition

Insensitive Munitions Technology

M777A2 Lightweight 155mm Howitzer

Excalibur

Gunner Protection Kits



M110 Semi-Automatic Sniper System

M240B 7.62MM Machine Gun

40mm Multi-Shot Launcher

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

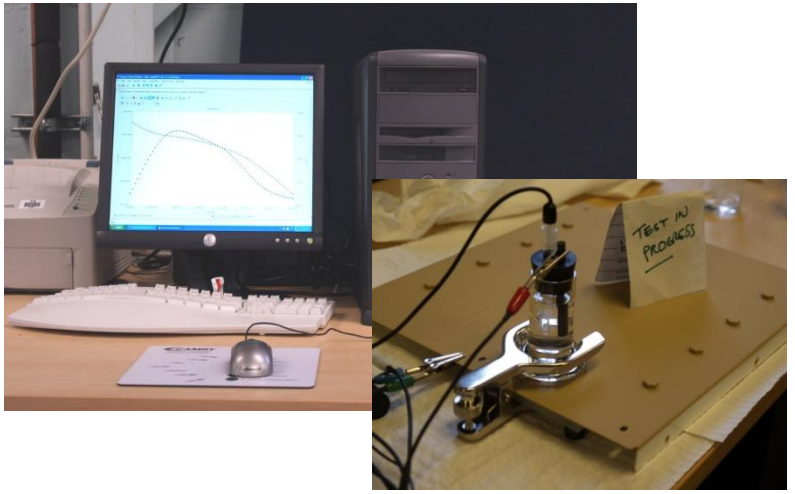
Overview:
In-House Corrosion Facility

Atmospheric Exposure

Cyclic Corrosion Chambers

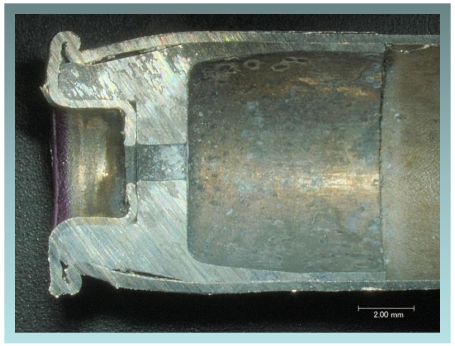
Weathering Chambers

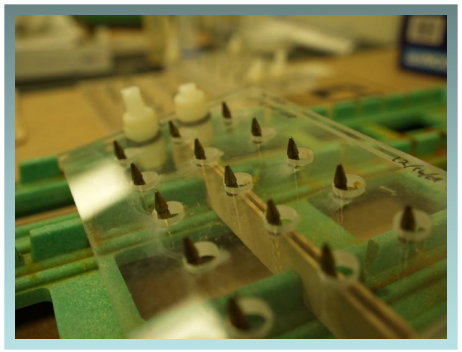
Electrochemical Analysis



Corrosion Studies

Several on-going corrosion studies at ARDEC related to Armament issues and concerns.





Studies:
Galvanic Materials

Project: Lightweight Small Cal Ammo

Courtesy of Wikimedia Commons (public domain)

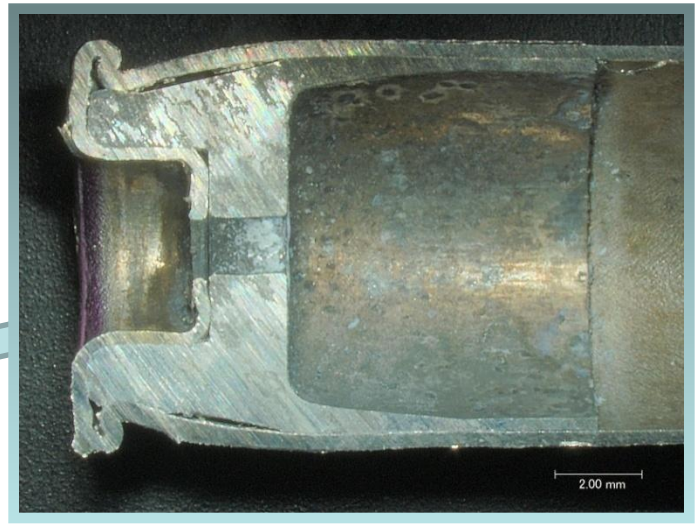
Background:

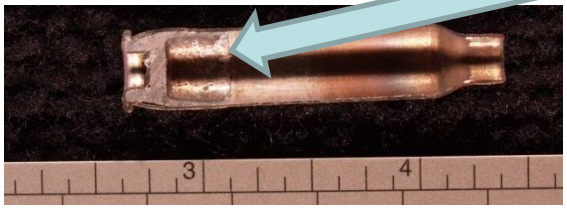
- Designing/developing stainless steel cartridge case
- For structural support inserting Al plug

Issue:

- Possible galvanic couples that could lead to corrosion
- 3 main galvanic couples of concern shown below:

1.	Plug Insert 7075 T6 Aluminum	Cartridge Case 305 Stainless Steel
2.	Bullet Jacket Cu Alloy 220	Cartridge Case 305 Stainless Steel
3.	Cartridge Links 1045 Carbon Steel	Cartridge Case 305 Stainless Steel





Studies:
Galvanic Materials

Project: Lightweight Small Cal Ammo

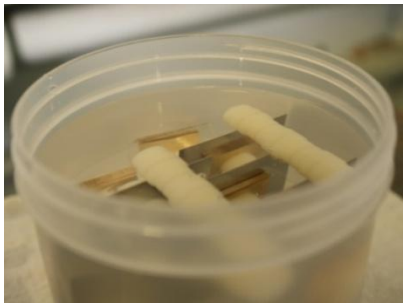
Representative Materials

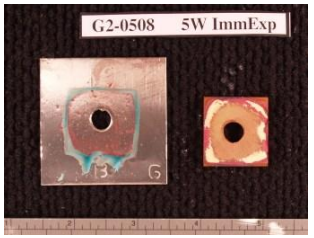
Testing:

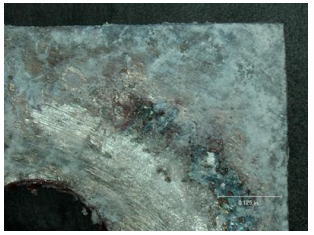
– Representative materials were selected and specimen set-ups were made for several different tests

Atmospheric Exposure

Constant Immersion

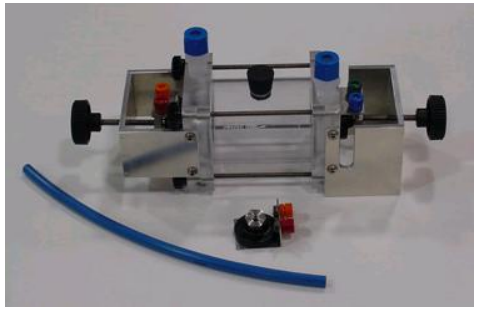


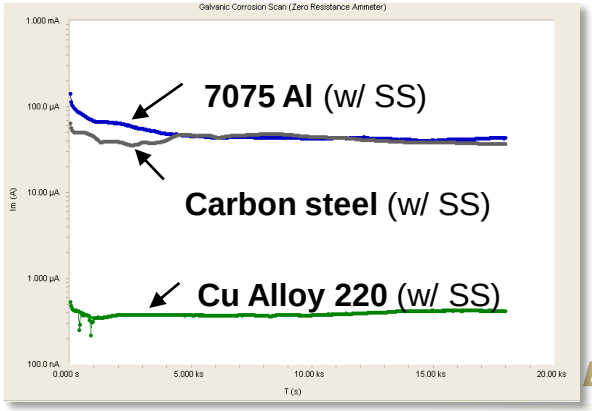




- Visual inspection
- Corr product analysis
- Weight loss
- Corrosion morphology and location

Zero Resistance Ammeter (ZRA) Test





- Plot galvanic current vs. time
- Used to monitor galvanic interactions b/w electrodes
- Corrosion potentials can provide info on sacrificial protection

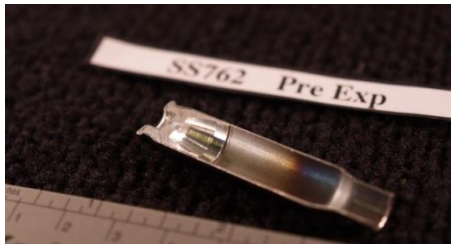
Studies:
Galvanic Materials

Project: Lightweight Small Cal Ammo

Actual Components

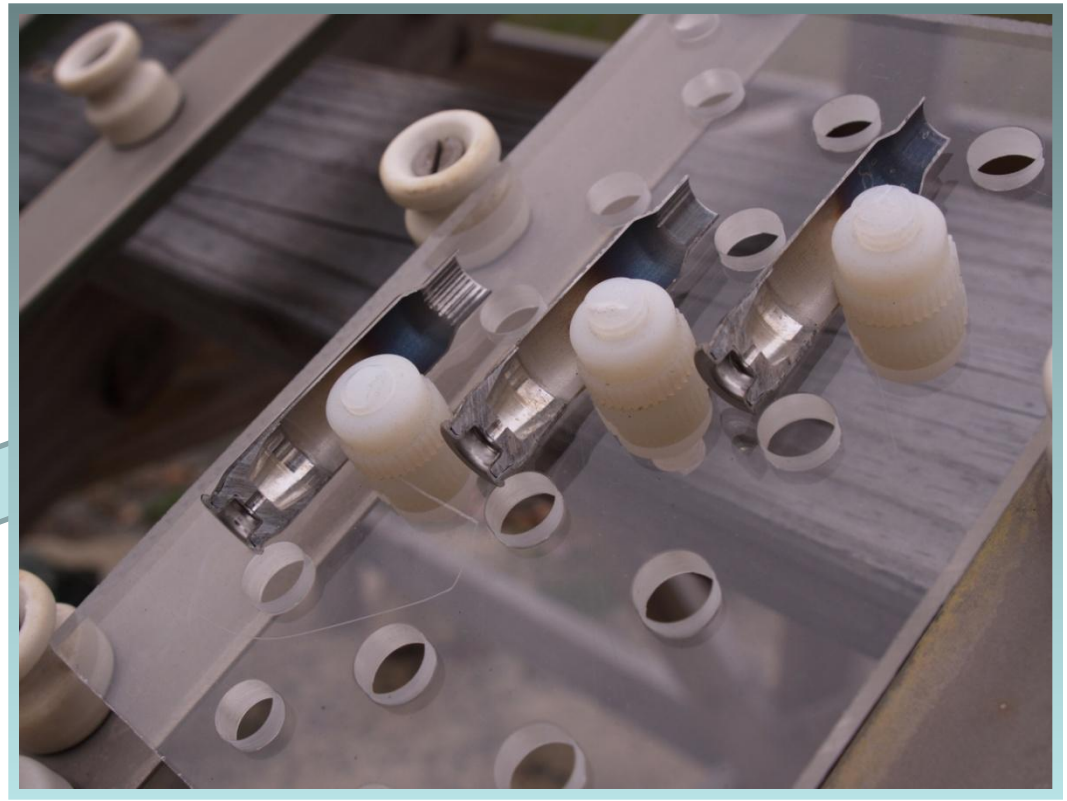
Exposures:

- Sample 7.62 SS cartridges cases were cross-sectioned lengthwise
- Specimen holders were designed to accommodate racks in atmospheric test yard
- Results will be compared with representative materials testing



7.62 SS cartridge after being cross-sectioned

Corrosion Instrumented Test Yard (CITY)
at Picatinny Arsenal, NJ



Studies:
Packaging Coatings

Project: **M2A1 Ammo Can Coatings**

Actual Components

Background:

- Looking for alternative coatings to current liquid dip alkyd to improve/maintain performance, cost and environmental impact

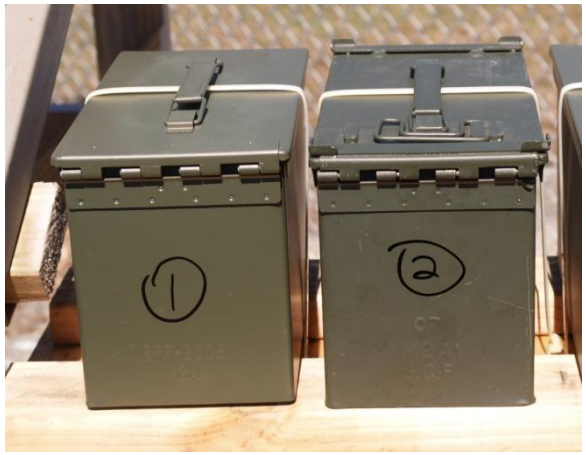
Issue:

- Epoxy powder formulation may be susceptible to UV degradation

Testing:

- Side-by-side exposure in Picatinny's Corrosion Instrumented Test Yard (CITY)

April 2009



September 2009

Studies:
Ammo Coatings

Project: Small Cal Green Bullet

Actual Components

Background:

- Program initiative to create an environmentally-friendly bullet design

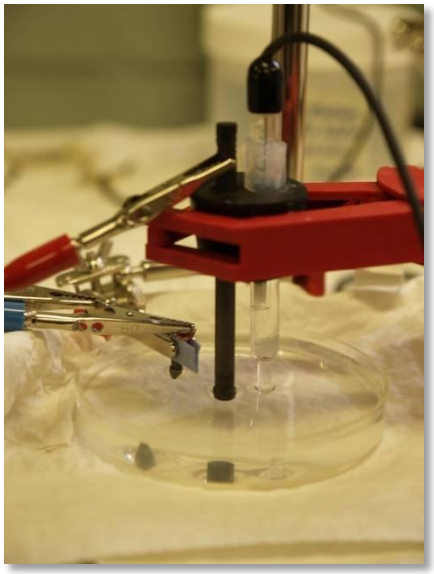
Issue:

- Need to test corrosion resistance of coatings for penetrator protection

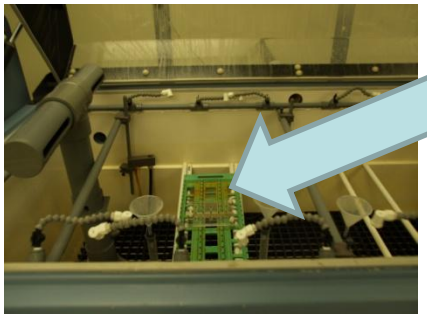
On-going Testing:

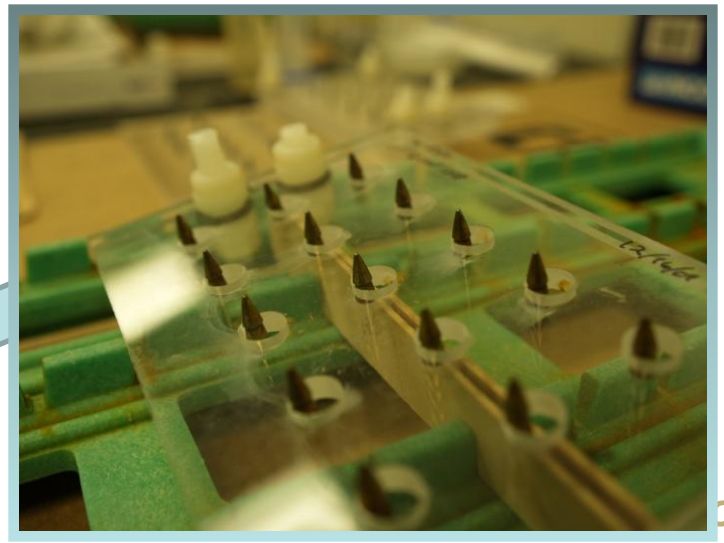
- Qualitative comparison in 48hr salt fog exposures (ASTM B117)
- Electrochemical assessment (E_{oc}, EIS, etc.)
- Plan to do atmospheric exposures

Electrochemical test set-up



Salt fog exposure in cyclic corrosion chamber



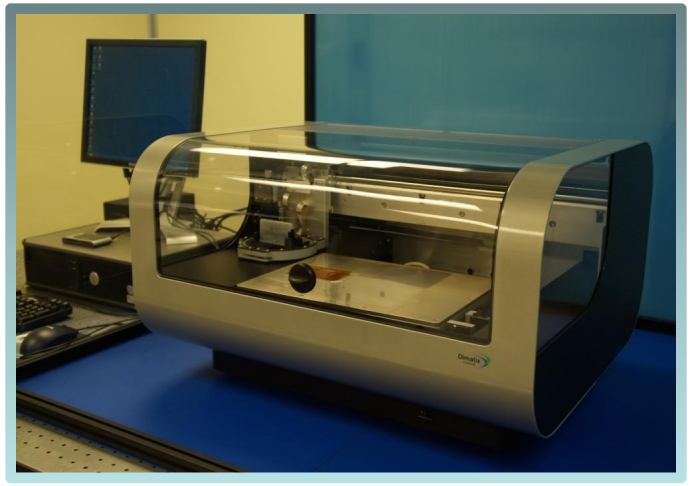


Studies:
Representative vs. Actual

	Representative Materials	Actual Components
Advantages	• Cost • Size • Availability • Security • Reproducibility	• Geometry (shape) • Interfaces and area ratios • Manufacturing steps • More realistic surfaces • Residual stresses

Materials Printing

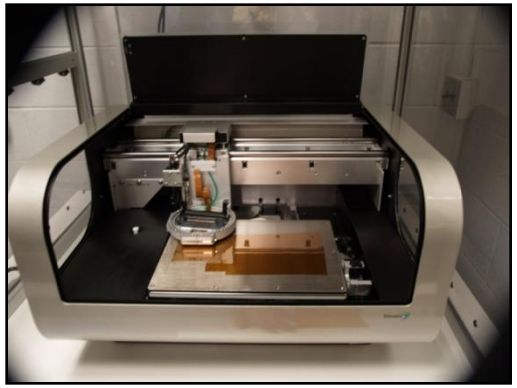
Sensor design & prototyping using materials printing



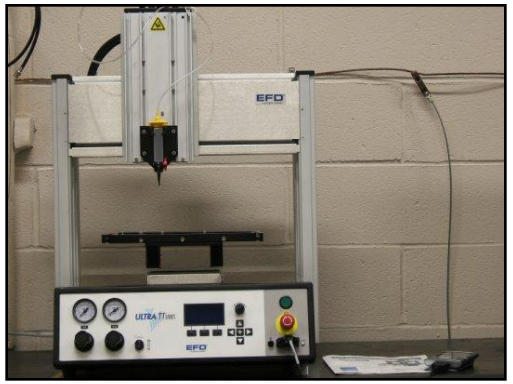
Materials Printing

What is MATERIALS PRINTING?

Nanoparticles (dispersed in solvents to form nano-inks) are deposited and then annealed to form patterns on a range of substrates.



Ink-jet Printing (Drop-on-Demand)



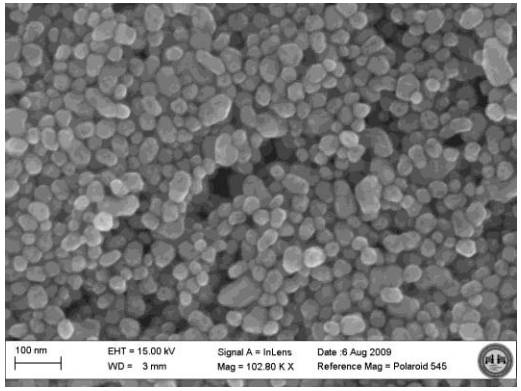
Direct Write

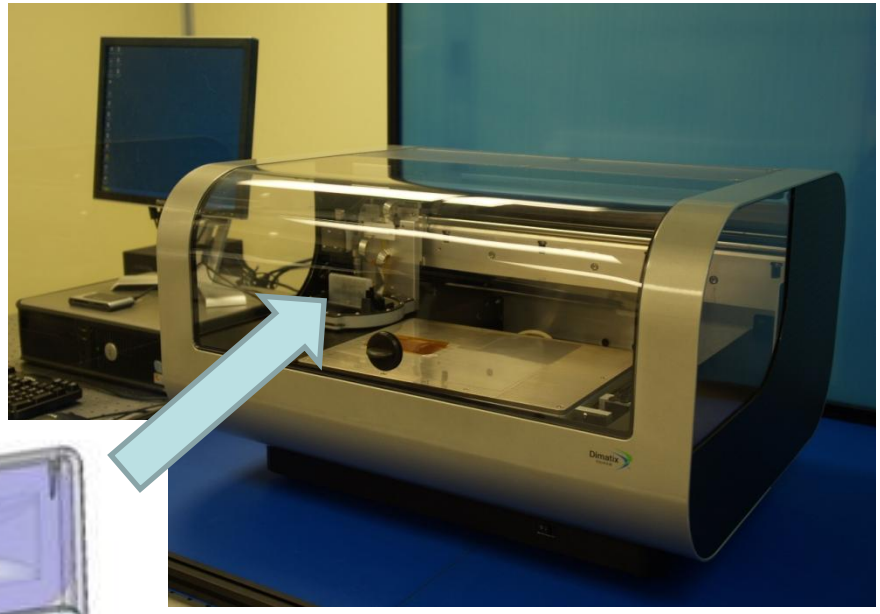
Why is ARDEC interested?

- flexible substrate = fit electronics & larger payloads into munitions
- tailorable effects and applications
- ease of manufacturing / versatility
- lower cost (eg. sensors, electronics, fuzing)
- advanced materials

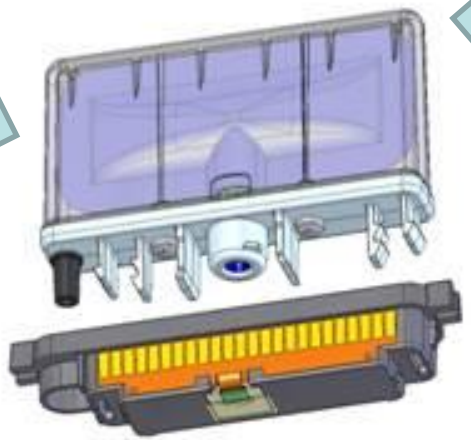
Materials Printing:
Cartridge & Inks

Nano-Inks

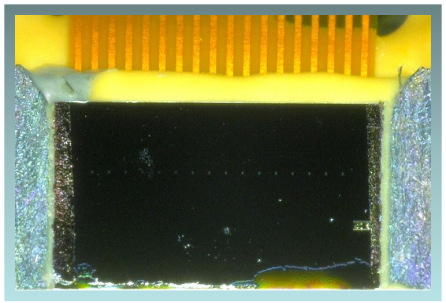




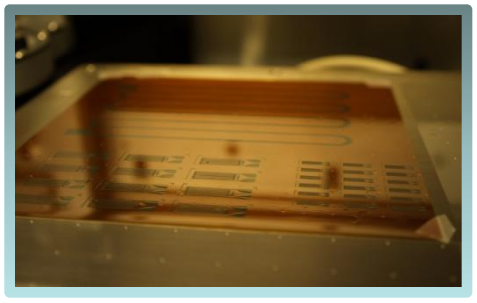
Dimatix Materials Printer System



Print cartridge



Bottom-up view of 16 piezo-controlled nozzles

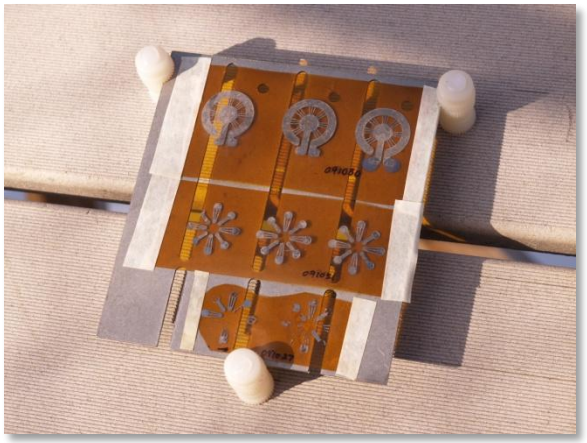


Ink deposited on flexible substrate (pre-anneal)

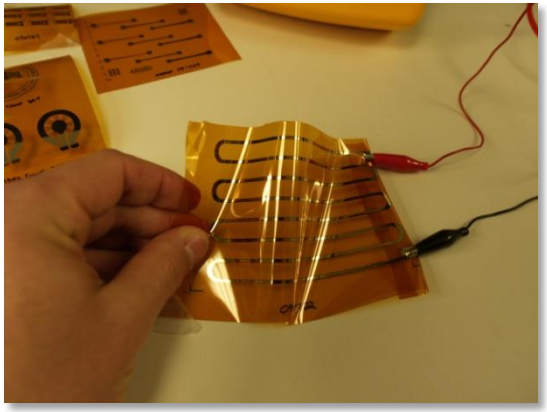
Materials Printing:
Select Devices & Components

Flexible Initiator

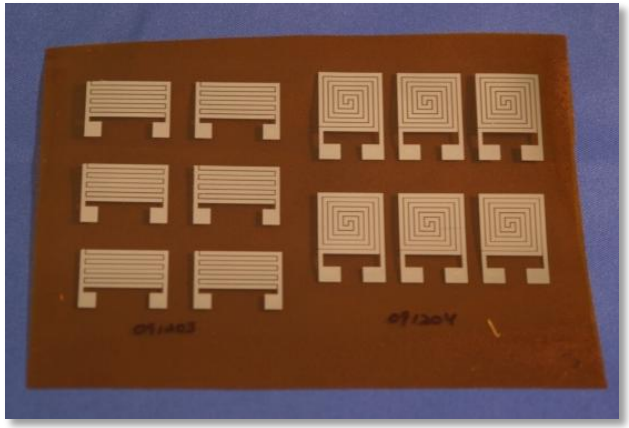
ARDEC Logo



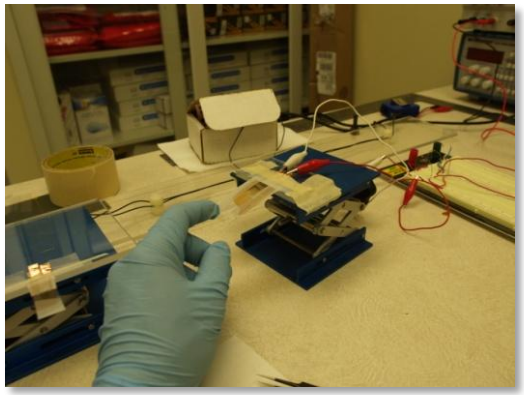
Corrosivity Sensors



Scratch Sensors



Capacitors



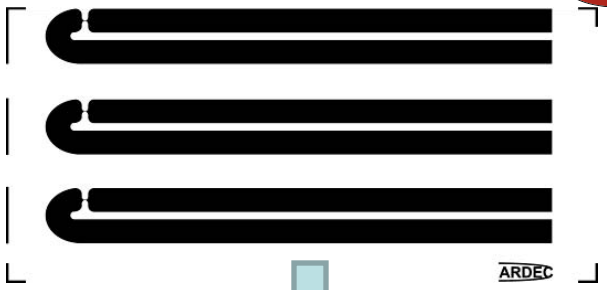
Strain Sensors

TECHNOLOGY DRIVEN. **WARFIGHTER FOCUSED.**

Materials Printing:
Flexible Initiator

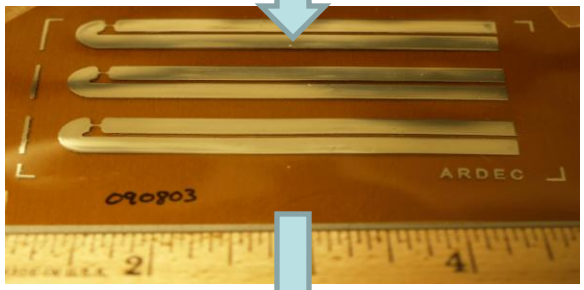
Designed

- used computer software to design pattern
- based on low voltage initiation of bridge-wire
- several iterations



Prototyped

- material selection
- refined ink-jetting process parameters
- annealing steps
- also several iterations



Tested

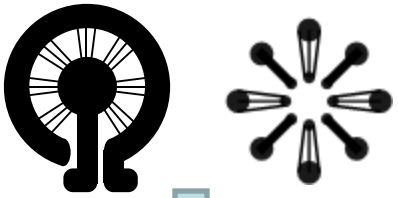
- loaded with primary and secondary explosives
- initiated devices with low voltages in blast chambers
- used witness plates to confirm detonations

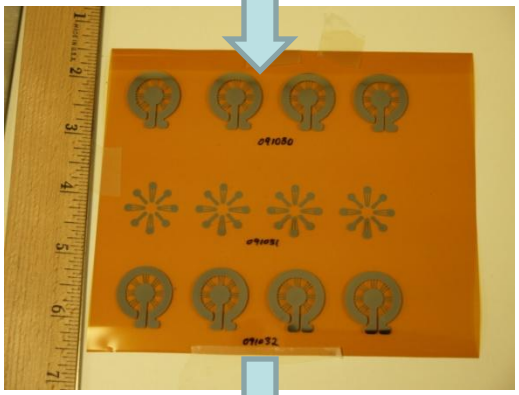
SUCCESSFUL
now patent pending

Materials Printing:
Corrosivity Sensors

Designed

- used computer software to create 2 designs
- based on resistance and visual changes
- initial iteration





Prototyped

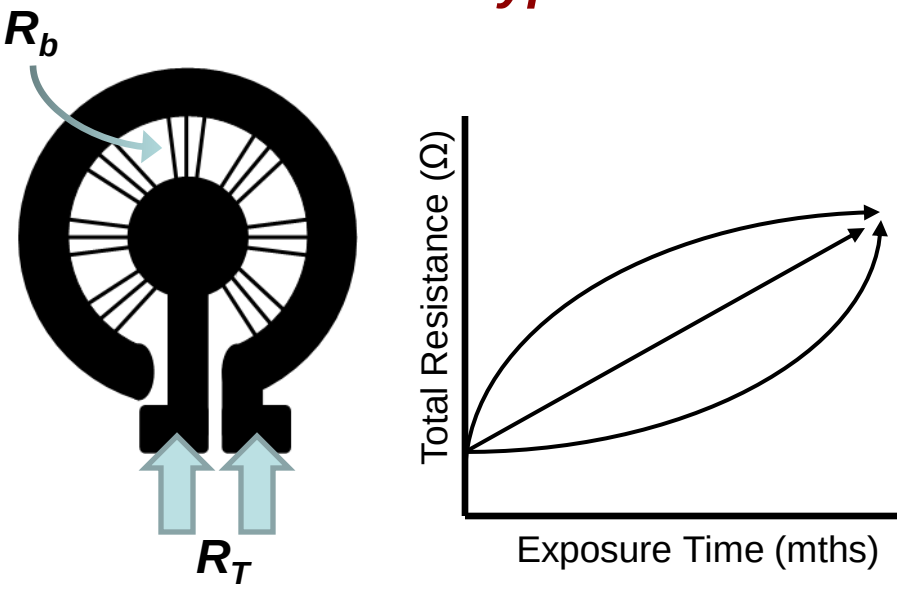
- material selection
- refined ink-jetting process parameters
- annealing and encapsulation steps
- initial iteration

On-going Testing

- initiated exposure in C.I.T.Y. (atmospheric test yard)
- measure resistance and take pictures
- correlate results with exposure time
- new materials and designs

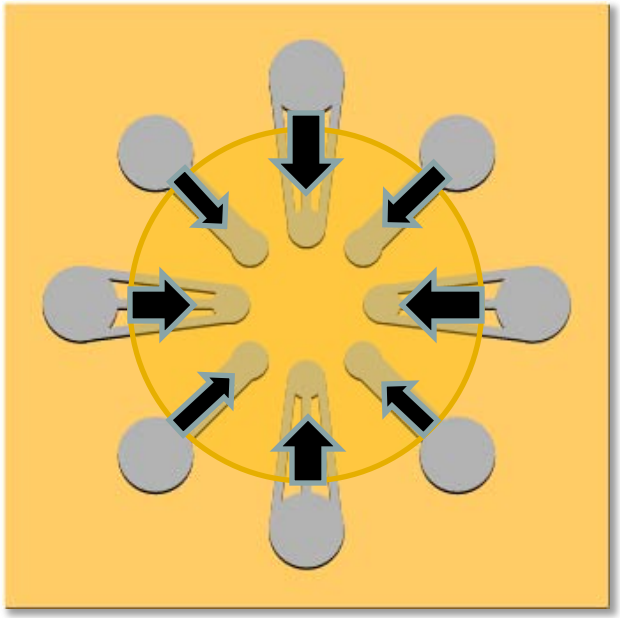
Materials Printing: Corrosivity Sensors

Sensor Type A



$$R_T = R_b / 21$$

Sensor Type B



Summary

- Several on-going corrosion studies at ARDEC
  - related to coatings and materials
  - atmospheric, chamber, lab-scale and electrochemical testing
  - using representative as well as actual components
  - developing new test methods
- Sensor design & prototyping using materials printing
  - several components have been made
  - corrosivity sensors currently being studied
  - plans for future designs and materials

Thank You!

Questions…ask now if you're *lost*.